What do network theory and endogenous risk theory have to say about the effects of central counterparties on systemic stability?

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Central counterparties (CCPs) alter the connectivity structure of financial institutions (FIs), and therefore the transmission of shocks. What does network theory have to say about the effects of CCPs on systemic stability, and how do different CCP structures (e.g. one vs multiple CCPs) alter systemic risk from a solvability point of view? CCPs not only alter the direct interconnection of FIs through their balance sheets, they also affect FIs and the links between them indirectly through prices. Prices are endogenous and are not only determined by the actions of the FIs, but they in turn constitute imperatives for FIs to act through marking-to-market and risk-sensitive constraints, both natural ingredients of CCPs. Could such feedback effects from CCPs amplify market movements and financial stress?

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One can imagine a wide array of reasons why in principle a move from OTC derivatives trades to central counterparties (CCPs) would have social benefits. For instance regulators would benefit from informational advantages due to one of the roles CCPs can play, namely the role of a data repository easily accessible by regulators. CCPs also can help in reducing counterparty risk through the combination of their own capital in the pooled guarantee fund as well as the initial and the variation margin posted by counterparties and the regular settlement features of profit and loss. However, little academic work has been done on this subject, and some research papers make the point that CCPs might not necessarily have social benefits only. For instance, Duffie and Zhu (2009) have shown that multiple specialised CCPs might lead to inefficient use of collateral. Some commentators have also mentioned the fact that systemic risk gets concentrated in CCPs, that the failure of a CCP would be truly catastrophic, and that if CCPs were linked in a network, there may be a domino effect of failures. On top of such balance sheet effects, the current crisis has highlighted the damage that self-fulfilling feedback effects through asset prices can have on the financial system, even in the absence of any bankruptcies. Would CCPs have reduced or inflated such externalities?

The aim in this short note is to think through costs and benefits, and to forewarn regulators and market participants of possible side effects of different CCP structures. Due to the lack of fully worked-out research papers on the subject of CCPs, we use this opportunity to imagine what the likely outcomes might be once CCPs have been integrated into a rigorous modelling of the financial system. This endeavour must be speculative by nature, but the hope is that the ideas might make policy makers aware of some of the possible unintended consequences of CCPs, both beneficial and detrimental.

We shall try to focus on those two effects that we believe will be crucial in determining whether CCPs will be able to live up to the high hopes for systemic stability that they have been endowed with: endogenous risk and interlinkages.

1| ENDOGENOUS RISK

The first effect CCPs will have on the financial system is that they have the potential to affect price dynamics in the financial markets. Securities prices are not simply net present values of future payments as they would be in a frictionless risk neutral world. Securities prices are determined by demand and supply considerations that themselves discount such future payments in a possibly risk-averse manner, but demand and supply are also subjected to many further effects, some of them institutional. The net outcome is that prices are subjected to fundamental payoff-related risk (prices embed fundamental security-related information and are fluctuating randomly to reflect innovations in such fundamental information) and to what has become known as *endogenous risk*,[1] which is the risk impounded into securities prices by the structure of the financial system. Overall risk is the sum of those two components, and given the feedback effects and amplification mechanisms at work in the markets through the endogenous risk channel, overall risk can be many times higher than fundamental risk. This is obvious to financial practitioners, and should be obvious to those who have lived through the current crisis.

A simple analogue might be helpful at this stage. The Millennium Bridge built in London to celebrate the new millennium suffered from exactly such endogenous and destabilising feedback effects. A small gust of wind (the fundamental shock) could set the Millennium bridge to sway a tiny bit. Pedestrians crossing the bridge slightly adjusted their stance as a response, pushing the bridge further in the same direction. Provided sufficiently many pedestrians found themselves in the same situation, they felt compelled to coordinate and lockstep, and they thereby reinforced the swaying into a rather wild wobble. The resulting swaying was many times more forceful than the fundamental one, which was a tiny initial gust of wind.

Similarly, as financial conditions worsen, the willingness of market participants to bear risk

1 *See the introduction paper by Danielsson and Shin (2003) or the formal models in Danielsson, Shin and Zigrand (2010) and in Danielsson and Zigrand (2008).*

seemingly evaporates even in the absence of any further hard negative news, which in turn worsens financial conditions, closing the loop. It appears to an outside observer that the "risk appetite" of a large part of the market participants disappears at the same time.[2] Such death spirals occur due to the coordinating effects of similar risk systems (e.g. Basel II inspired value-at-risk—VaR rules), of regular settlement and marking-to-market leading to regular margin calls.[3] They also appear if delta hedgers are net short gamma or engaged in similar programme trades (the crash of 1987 or the "flash crash"' of May 6th 2010 come to mind).[4] If one financial institution (FI) needs to sell a security due to a pickup in volatility, its sale depresses prices. Other financial institutions will need to mark their positions down, will need to honour margin calls, and have their own risk systems prompting a reduction of risk because of the joint effect of higher volatility and lower capital. This in turn reinforces the downturn, and the loop closes.[5] The effects are identical to the reinforcing locked steps on the Millennium Bridge. The prudent and conservative actions that any one individual institution takes to enhance its soundness may undermine the soundness of others. This fundamentally important insight, which can be dubbed "the *fallacy of composition*," forces regulators to rethink regulations since for the system to be safe, it is not sufficient for each institution to be safe. To the contrary, making any one institution safe may weaken the overall system depending on the precise nature of the regulations that were meant to make each institution safe. It is tempting to design regulations whose first order effects are common sensical and go in the right direction, but unfortunately one cannot understand the mechanisms underlying financial crises without keeping this simple point in mind: in precisely the precarious situations for which the rules have been designed, the unintended nonlinear second order effects dominate the first order linear ones.[6] Some of the regulatory responses to the crisis were more reminiscent of attempts to outlawing the gust of wind or of closing the bridge (and leaving pedestrians stranded) than to finding ways to prevent pedestrians from lockstepping.

While there probably are no reliable data on the precise extent to which financial institutions have hitherto regularly marked-to-market OTC exposures, called for collateral and managed margins and haircuts in response to market developments, it would appear that many institutions have managed such exposures to some extent as would a CCP have done. While not exactly comparable, daily collateral exchanges play the role of daily margin calls, and up-front collateral (known as the "independent amount") plays the role of the initial margin. Still, there is little doubt that a sufficiently large part of the OTC exposures have not been dealt with in this way, and some well known cases of under collateralised exposures are known.[7] [8] My guess is that for an otherwise identical amount of derivatives trade, CCPs will increase aggregate marking-to-market and regular margin calls, potentially reinforcing the existing feedback spirals. CCPs being central and systemically important, they will have no choice but to religiously insist on margining. They cannot temporarily suspend marking-to-market and regular settlement, unless governments come in with guarantees or central banks offer back-stops. Also, it would appear that over collateralisation of

2 *It appears that asset returns are driven by a latent risk appetite factor. This factor is relevant to central banks that compute this factor in the normal course of events, see for instance ECB (2007) and the methodology devised by Gai and Vause (2005). Indeed, risk tolerance and financial crises are inseparable, see for instance Coudert and Gex (2008) for an empirical analysis. In Danielsson, Shin and Zigrand this risk appetite factor is endogenised and is driven by the capitalisation level of the financial sector.*

3 *A bank must of course mark-to-market its books for risk management purposes. The insidious effects of marking-to-market arise when through marking-to-market FIs are forced to mechanically adjust their positions.*

4 *For instance, Gennotte and Leland (1990) make this point. But endogenous risk is more general because the "strike price" beyond which feedback effects pick up is made endogenous. The amplifications from delta hedging of put options only occur where gamma is highest, which is around the strike, but the strikes of the portfolio protection strategies are by themselves a choice variable.*

5 *Contagion does not have to be limited to risky securities: with Government bailouts contagion can feed through to sovereigns, as correctly predicted by Jassaud (2009).*

6 *This point has been made also in Danielsson et al (2001) on the equilibrium effects of Basel II.*

7 *While no objective data sources seem to exist, it would appear (also see Singh, 2010) that many privileged entities (such as Freddie Mac and Fannie Mae, AAA insurers such as Berkshire Hathaway and AIG, or institutions such as European Bank for Reconstruction and Development –EBRD) have not posted upfront collateral. Also, dealer to dealer banks do not usually post collateral between each other in light of the many offsetting trades, at least not until such point as too large an imbalance builds up. Exposures to sovereigns and corporates also tend to be under collateralised. ISDA for instance states that 70% of OTC derivatives trades are collateralised, though it is not clear whether those 70% are fully collateralised, nor is it clear what fraction of OTC derivatives* value *is collateralised. For instance, based on a recent survey (ECB, 2009), it would appear that EU bank exposures may be collateralised well below this. Singh (2010) estimates that the degree of under collateralisation is about USD 2 trillion for residual derivative payables.*

8 *Notice also that hedge funds will not make much of a difference to margining given that they already post both up-front and daily collateral, and that their exposures are generally over collateralised. The regulatory scrutiny of hedge funds seems to be motivated by factors other than systemic stability.*

the independent amount reduces the need for daily margin calls in the OTC world, making a move to CCPs more pro-cyclical still.[9] This effect needs to be contrasted then to the volume of derivatives that is likely to be traded after CCPs become mandatory for the eligible contracts. There might be more trade (say since counterparty risk is lessened, or since markets become more transparent and potentially more competitive, not least due to reduced post-trade costs) or there might be less (say since trading derivatives may become more onerous and capital intensive, not least due to marking-to-market). While the net effect is not known at this stage, it would be fair to presume that both volumes and feedbacks will increase.

Now imagine an economy with more than one CCP and contrast it to the otherwise identical economy with only one CCP. Imagine FI number 1 trading with FI number 2. Imagine also that the FIs have two exposures that pretty much net out. This is a very frequent situation. If both are cleared by the same CCP, then a deterioration in the markets leads to no margin calls, and the endogenous risk channel will not be materially magnified by those two exposures. But if both are cleared on two separate CCPs with no links between the two, an increase in volatility will lead, regardless of the direction of the markets, to margin calls and a selling of risk.[10] Since capital is difficult to come by instantaneously, the prudent action of any one of the two institutions involved is to reduce its overall risk, probably partly by selling risky securities, and probably by selling those risky securities that can be sold. It follows that chances are that effective risk aversion will have been increased in the markets and that asset prices fall, increasing correlations as a result, since other FIs not involved with 1 and 2 will also need to adjust their risk. Those effects in turn will lead to the closing of the feedback loop through higher risk measures and lower capital. Evidently, this example is overly simplified (FIs will attempt to clear the trades on the same CCP), but it does provide another angle, the endogenous risk angle, to the question as to whether the number of CCPs matters. People have argued that multiple CCPs may lead to inefficient use of collateral, see for instance the recent paper by Duffie and Zhu (2010), but we would add that a further worry is that multiple poorly coordinated CCPs will not only require more collateral, they will make the collateral – and markets – potentially less safe from a macro-prudential point of view by increasing the negative externalities.

Cross-margining would mitigate this worry of an increase in endogenous risk. For instance, not only does the Options Clearing Corporation (OCC) act as a clearing house for the majority of options products traded on the majority of US exchanges, yielding netting benefits that reduce feedback loops, the OCC, ICE Clear US and the Chicago Mercantile Exchange (CME) have also operated cross-margin programmes for a number of eligible products for many years.[11] Initial margin is reduced as a result and net settlements are smaller. This would be the way to reduce feedback effects from margining. Another hub structure that is of a link arrangement type has been established in Europe (see Kalogeropoulos *et al.* (2007) for the details) between OMX Derivatives Markets (acting as the hub), LCH.Clearnet and VPS clearing ASA. Again, contractual arrangements have been established without a CCP being a member of the other CCPs. Maintenance margin calls across CCPs are financed in the form of cash or an increase in a bank guarantee.[12] [13] While cross-margining

9 *Pro-cyclicality could also become temporarily higher if FIs move from under collateralised OTC to more fully collateralised CCPs due to the fact that collateral is typically cash or highly rated sovereigns. If FIs have trouble finding this collateral, they might then be tempted to sell out of riskier securities, raising risk aversion in the markets.*

10 *The same effect will appear if one exposure goes to a CCP while the other one remains bilaterally cleared.*

11 *In a nutshell, a joint (across CCPs) clearing account for each member is established. The OCC acts as a sort of netting agent and central hub CCP of CCPs and maintains the account, computes the relevant margins and then distributes position, margin and settlement reports to clearing members.*

12 *In a systemic downturn, it is likely that the values of the bank guarantees themselves drop pro-cyclically, making bank guarantees perhaps not the ideal instrument for links on a larger scale.*

13 *Contrast this to the ongoing debate in the European cash equity markets where LCH.Clearnet, EMCF, X-clear, Euro CCP etc. have been in the process of trying to forge "interoperability" links with each other, whereby a trader has the choice where a trade executed on a given trading venue is sent for clearing. The trader can then send all trades for clearing to the same CCP, generating an off-set of margin. Since the two counterparties to the trade may send the trade to different CCPs, cross-CCP positions arise (since one CCP now becomes a counterparty to the other one in lieu of the original counterparty) that need to be dealt with. In particular, interoperability is feared to introduce potentially systemic exposures across CCPs that a form of inter-CCP margining must address. We return to this point. The same interoperability may be established across derivatives CCPs, where CCPs and interoperability take on a role of a larger order of magnitude yet compared to cash equity. The difficulties in getting European cash equity CCPs and regulators to agree on an interoperability model in cash equities may be due to the fact that counterparty risk mitigation is relatively small in cash equities, and that it would seem rather more likely that such an agreement can be struck in the complex market of derivatives clearing where counterparty risk mitigation is crucial.*

unambiguously reduces endogenous risk, we would expect cross-participation and link arrangements to do so as well, although the argument would to some extent depend on the type and liquidity of the assets held by the CCP that is a member of another CCP.

There is a related point having to do with the feedback effects caused by marking-to-market and the push towards exchange-based trading. There is no obvious solution to the fact that many securities are illiquid, which makes it hard to find the true value for mark-to-marking. The marks will appear to be the "officially correct audited market prices" and it might well be those marks that all FIs will have to use for marking their books to, even if the superior valuation capacities of a given FI imply that the FI knows the mark to be dangerously off.[14] To summarise, if illiquid and immature OTC products are forced onto CCPs, not only may the CCP be poorly equipped to manage the risk imbedded in these products and run the risk of failing,[15] the negative feedback externalities arising from the fact that the price set by the CCP will constitute an imperative for all counterparties to adjust their own marks, increase systemic risk. The crisis shows clearly that liquidity can dry up very quickly, and that the resulting impossibility to smoothly mark all positions to market was a contributor to the extent of the crisis. In that sense the *fallacy of composition* appears in a different context: it is not true that if all products are cleared, and therefore appear to be safe, that the system overall is safe. Indeed, it probably is safer to only require clearing of products that are mature and well understood.

Finally, endogenous risk and pro-cyclicalities may arise depending on the way the guarantee fund is replenished. If the guarantee fund is replenished through risk-sensitive rules, such as VaR, the CCP will ask for capital in periods of turmoil and will return capital in quiet times, everything else equal.[16] Uncertain times are usually times where capital of FI comes under pressure. Calls to stock up the capital at the CCP will therefore likely be met in the short run through sales of risky assets and through increases in haircuts from borrowers (such as through repos), reinforcing the pro-cyclicality of markets.

2| INTERCONNECTEDNESS

Network theory is a relatively young branch of research in finance. Most network papers applied at regulatory or central bank level are of the pure domino type. The interlinkages are balance sheet interlinkages, and the insolvency of one bank can lead to the insolvency of another bank that is exposed to the first bank, and so on. A fair conclusion would be that these domino network models have led to the conclusion that the potential for a systemic breakdown is very small in that only implausibly large shocks fed into the simulations lead to meaningful contagion.[17] This is partly due to the fact they are missing the endogenous risk component of contagion which can amplify downturns dramatically.

Let us first consider a domino type economy with no CCP. The FIs have established balance sheet links between each other, and these links are common knowledge.[18] Which network is more robust to balance sheet shocks, a dense complete network, a largely disconnected sparsely linked one, or something in between?

We can use the recent model by Cabrales, Gottardi and Vega Redondo (2010) as a guide. The authors assume that the links across banks are not interbank deposits but securitisations of bank assets. Banks

14 *CCPs have established procedures to try to mitigate this risk through consensus based official end-of-day settlement prices determined on the basis of market prices, prices submitted by member firms and/or theoretical model prices, and then adjusted to represent executable market prices. For instance, in 2009, ICE Clear Europe adopted procedures requiring clearing members to randomly implement trades at prices generated by their indicative settlement prices. Little academic research seems to have been done on the accuracy of this settlement price, and little information is publicly available as to the frequency and notional value of such forced trades, if any. Eurex says it implements an additional liquidity margin.*

15 *In order to actually fulfill its role to reduce counterparty risk, the CCP needs to figure out the right margins and the likely number of days it takes to unwind any trade that the CCP may inherit from defaulting members, as well as the required size of the guarantee fund.*

16 *Unfortunately, none of the CCPs seem to publish the details of their VaR and stress-testing rules governing the additional contributions to their guarantee funds. Leaving market participants in doubt as to the effects on systemic stability of those institutions that are supposed to provide the markets with systemic stability in the first place is unlikely to be reassuring.*

17 *For an interesting paper in this spirit with random connections, but with CDS contracts, see Cont and Minca (2009), who compute their systemic risk measure without a CCP and with one CCP.*

18 *We return to the question of network formation. Here, as in the vast majority of financial network papers, the network is considered as given. The assumption that the network is common knowledge is a very strong one to which we return.*

securitise their assets and acquire a fraction of some of the other banks' assets. Banks can be hit with shocks whereby some of the assets turn bad. There are frequent small to medium size shocks to banks as well as the potential of a rare but large shock affecting one of the banks. The large shock is modeled using distributions that may exhibit fat tails. There is no lender or market maker of last resort. All of the structure is common knowledge. In contrast to Allen and Gale (2000), in this setup the authors find that when indeed the distribution of the shocks exhibits fat tails, an intermediate level of connectivity is on average most able to resist the propagation of shocks. In a sparsely connected network, even small shocks will ruin the affected connected banks due to insufficient securitisation, while in the fully connected network the bad shock is able to bring down the entire system (but the small shocks can be mutualised). In an intermediate system the small shocks can again be diversified, while the bad shock only brings down part of the system due to the fact that not all banks are exposed to the shock, directly or indirectly. In a nutshell, the mixture of the distributions of the small, intermediate and large shocks determine the optimal network structure.

Now let us imagine that one central node (playing the role of a non-specialised CCP) is introduced. It would then appear that each FI sells part of its overall balance sheet to the central node through securitisation. In effect, each FI then swaps part of its balance sheet with the aggregate balance sheet of all FIs linked to the CCP.[19] With a single CCP, the effects should be similar to the ones in the completely connected network. With two or more CCPs that are not directly linked, and that are only weakly indirectly linked, the network would presumably be more flexible than the one with one CCP only if the big one is drawn from a fat tailed distribution. If the multiple CCPs are fully linked in the sense of swapping the securitised balance sheets of its members, the big one would bring the entire system down.

Three comments are in order.

First, most financial network models consider a network as a given or as randomly generated. They do not model the formation of the network. In Rahi and Zigrand the (static) network is determined in a network formation game whereby FIs establish links at a Nash equilibrium, each FI taking into account the links formed by all other FIs. It is shown there that network formation is subjected to a prisoners' dilemma and the equilibrium network is always inefficient. The network maximising FI value is a hub and spoke network with one particular central hub. This central hub plays the role of a CCP since all trades must pass through it and are fully collateralised. Although market liquidity is maximised, due to the prisoners' dilemma feature, this central hub must be imposed through regulations.

Second, and unfortunately, if there are multiple CCPs, the current theoretical models are unable at this stage to determine the exact form of interoperability of those multiple CCPs, whether the CCPs network is complete and either (i) making each CCP a member of each other CCP and contribute initial and variational margin or (ii) asking CCPs to set extra capital aside as a buffer against other CCPs failing without imposing any margins,[20] or whether indeed the CCPs should be set up in a hub and spoke network with the cross-margining undertaken by the hub as a netting agent, or any other form of linkage.

Third, the network structure in all of the network models we are aware of is common knowledge. We cannot point to any academic papers that have fully analysed the damaging effects of informational intransparency (such as the extent of under-collateralised OTC derivatives exposure of any one FI in the network with any other FI, or the fine print in the bilateral agreements among different CCPs that currently are confidential commercial contracts) on the magnification of

19 *This is shown to be both the optimal and the equilibrium asset structure in a security design game where the securities are not all given but can be innovated by the FIs, see Rahi and Zigrand (2008).*
20 *This approach, broadly proposed by EuroCCP for cash equities, might reduce liquidity and endogenous risk up to a point.*

the transmission of shocks in networks. The idea would be one of uncertainty versus risk. While the FI is not overly bothered with transparency when the party is in full swing and risk appears low, in a crisis however risk aversion increases and behaviour changes. If in a crisis a FI does not know the connectedness of counterparties and the extent to which those exposures are fully collateralised, perhaps the FI rationally acts according to a robust control methodology, maximising its own objective function while preparing for – and expecting – the worst. This way of behaving has been put forward as a way to understand the freezing of the interbank and repo markets and the large holdings of cash by banks, which in turn made the downturn more brutal.

We can now merge the two themes of endogenous risk and of interconnections. On one hand we conjectured that a financial system with one or with multiple but fully linked CCPs (linked in the securitisation sense) may be less able to withstand the big one (if the big one hits only one of the FIs). It must be emphasised that this experiment was a static domino experiment and that market prices played no role. On the other hand, with market prices subjected to endogenous risk, multiple unlinked CCPs exacerbate the downward spirals that spread and worsen financial crises since prices coordinate the actions of all players, whether directly linked or not. Furthermore, if intransparency of the financial network reduces risk appetite in times of crisis, multiple unlinked CCPs further amplify the crisis dynamics. As often, there are two opposing effects. The net effect would depend on the trade-off between the magnitude of the initial exogenous shock and the strength of the feedback effects. Perhaps when reviewing the current crisis that emanated from the subprime segment, it would appear to this author that the latter have dominated the former in that the crisis seemed to have been made much more ferocious by the workings of the financial system itself, compared to what the initial subprime shock would have suggested, and that while Lehman's default did play a large role, the dominos created perhaps less contagion than the market price dynamics did.

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